IMPACT OF ENERGY SPREAD OF ELECTRON BEAM ON ABSORBED DOSE DISTRIBUTION

V.T. Lazurik[1], V.M. Lazurik[1], G.F. Popov[1], Yu.V. Rogov[2], G.E. Sarukhanian[2], V.V. Vereshchaka[2]
[1]V.N. Karazin Kharkov National University, Kharkov, Ukraine;
[2]National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
E-mail: gsar000@mail.ru

The results of numerical research on dependence of absorbed dose on energy spread of electron beam with two-sided irradiation are presented in this paper. The dependence of change in value of absorbed dose in the critical point on spectrum width of electron beam is shown. The dependence of dose uptake ratio on energy spread of electron beam is found.

PACS: 87.53.Bn

INTRODUCTION

At present, among the radiation-technological processes the technologies of disposable medical products sterilization are of a great importance, for they are directly connected with human health and life activity. Despite the fact that today thermal and chemical methods of sterilization are widely used as well as gamma radiators, in many developed countries the method of sterilization by electron beams generated by industrial high-power accelerators is becoming more and more popular [1]. However, this method has several drawbacks, one of which is strong dependence of dose uptake ratio on electron beam energy. For example, in case of using two-sided irradiation, a 1% change of electron beam energy can result in 7% change of absorbed dose value in the critical point. For timely detection of main parameters change there is a dosimetric wedge and devices for measuring absorbed charge [2]. The most probable and average energies of electrons are considered to be the electron beam main parameters, the change of which can be detected by these devices. However, the authors consider the spectrum width (of energy spread) of electron beam also to be an important parameter. In previous papers the authors showed that at two-sided irradiation the change of spectrum width of electron beam can affect the absorbed dose distribution more significantly than it is commonly believed [3]. After all, it is still unknown to what extent energy spread of electron beam affects the absorbed dose distribution. To answer this question, in this paper the research on dependence of absorbed dose value in the critical point on spectrum width of electron beam has been carried out by means of computer simulation.

MODEL AND RESULTS

At present, one of the basic ways to solve such problems is computer simulation by Monte Carlo method of generation processes of ionizing radiation and its propagation through heterogeneous objects. The basic calculations were carried out by means of specialized software module ModeRTL, which is included in program package RT-Office intended for simulation of radiation-technological processes [4].

In the paper a 3D model of sterilization facility is used. Its diagram is shown in Fig. 1.

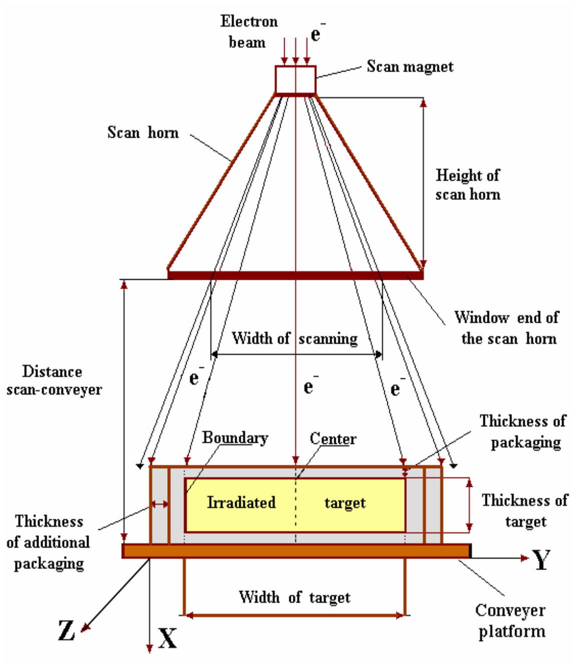

Fig. 1. Diagram of sterilization facility

It was suggested that spectrum of electron beam had a triangular shape, which is commonly used during experimental data approximation.

The function describing the spectrum is as follows:

$$y(E)=\begin{cases} h(E-E_{\min})/(E_p-E_{\min}), & E_{\min}<E\le E_p \\ h(E-E_{\max})/(E_p-E_{\max}), & E_p<E<E_{\max} \\ 0, & E\le E_{\min}\vee E\ge E_{\max} \end{cases},$$

where E_p is the most probable electron energy in beam, $E_{\min}$, $E_{\max}$ are minimum and maximum electron energies in beam, $h=y(E_p)=2/(E_{\max}-E_{\min})$ is maximum of function $y(E)$.

Parameters $E_{\min}$, E_p and $E_{\max}$ are connected with values of the average energy of electrons in beam E_{av} and full width of spectrum on the half of maximum E_w by the following formulas: $E_{\min}=1.5E_{av}-E_w-0.5E_p$, $E_{\max}=1.5E_{av}+E_w-0.5E_p$.

Due to these formulas it is possible to derive values of maximum $E_{w\max}$ and minimum $E_{w\min}$ spectrum width, with given values E_p and E_{av}:

ISSN 1562-6016. ВАНТ. 2013. №4(86)

$$E_{w_{\min}} = 1.5E_p - 1.5E_{av}, \quad E_{w_{\max}} = 1.5E_{av} - 0.5E_p.$$

During the research a series of numerical experiments has been carried out. The value of the most probable energy of electrons in beam ranged from 1 to 10 MeV, and ratio E_p/E_{av} took values from 1 to 1.4. The following materials were considered as targets: water, polyethylene and aluminum. Target optimization was carried out with minimum $E_{w\min}$, maximum $E_{w\max}$ and average spectrum width of electron beam $E_{w0.5}$ (E_w/E_p=0.5).

Fig. 2 shows the change of absorbed dose value in the target center at two-sided irradiation in case of increase of spectrum width of electron beam (target optimization was carried out with minimum spectrum width $E_{w\min}$, $E_p/E_{av} = 1$).

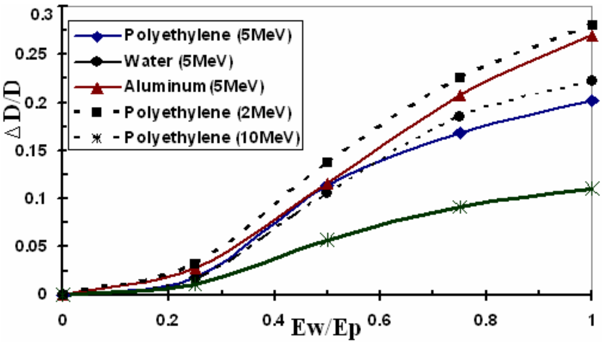

Fig. 2. Change of absorbed dose value in the target center with increase of spectrum width of electron beam

Fig. 3 shows depth distribution of absorbed dose at different values of spectrum width E_w (polyethylene target optimization was carried out with the average spectrum width $E_{w0.5}$, E_p =5 Mev, $E_p/E_{av} = 1$).

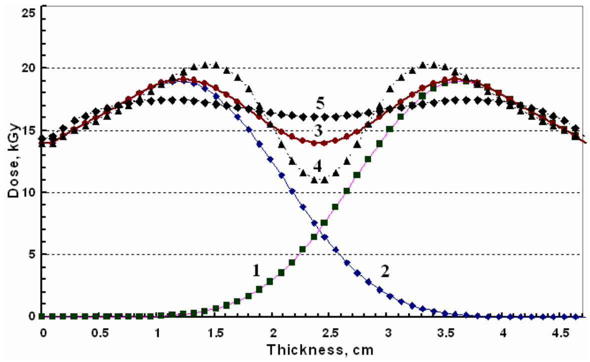

Fig. 3. Depth distribution of absorbed dose;
1, 2 – distribution of absorbed dose after one-sided irradiation from opposite sides with $E_{w0.5}$;
3, 4, 5 – distribution of absorbed dose after two-sided irradiation with $E_{w0.5}$, $E_{w\min}$ and $E_{w\max}$, respectively

Fig. 4 shows the change of absorbed dose value in the target center at increase and decrease of spectrum width (target optimization was carried out with the average spectrum width $E_{w0.5}$, E_p =5 MeV).

As follows from the above Figures, the absorbed dose value at decrease of spectrum width changes more significantly than at increase. Also it should be observed that at spectrum width decrease the change of absorbed dose value in the critical point leads to increase of dose uptake ratio.

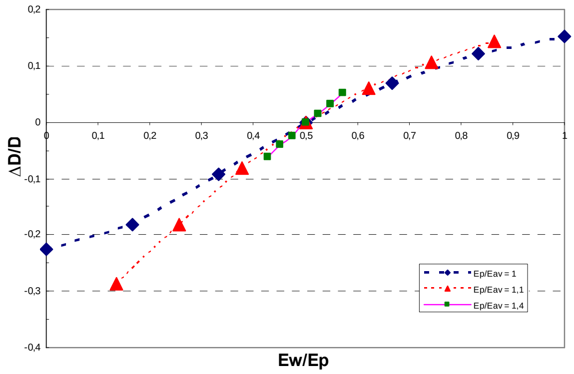

Fig. 4. Change of absorbed dose value in the target center at variation of spectrum width of electron beam

Fig. 5 shows the change of absorbed dose value in the target center at decrease of spectrum width (target optimization was carried out with maximum spectrum width $E_{w\max}$, E_p =5 MeV).

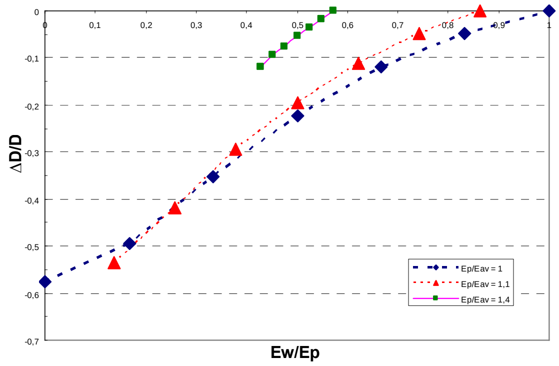

Fig. 5. Change of absorbed dose value in the target center at decrease of spectrum width of electron beam

As follows from Fig. 5, the decrease of spectrum width can change the absorbed dose value in the critical point more than twofold.

CONCLUSIONS

Taking into account the obtained results we conclude that during sterilization of products by electron beams it is necessary to carry out target optimization with minimum spectrum width, for in case of spectrum width increase, the dose uptake ratio will decrease insignificantly and this will not have any profound effect. Otherwise, at decrease of spectrum width, the dose value in the critical point can change significantly, which will lead to sharp increase of dose uptake ratio.

It should be noted that not taking into account spectrum width can negatively affect the quality of products sterilization. That is why it is necessary to expand the range of instruments for electron beam diagnostics, which will allow to forecast accurately possible deviations of absorbed dose values.

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Article received 28.03.2013.

ВЛИЯНИЕ ЭНЕРГЕТИЧЕСКОГО РАЗБРОСА ЭЛЕКТРОННОГО ПУЧКА НА РАСПРЕДЕЛЕНИЕ ПОГЛОЩЕННОЙ ДОЗЫ

В.Т. Лазурик, В.М. Лазурик, Г.Ф. Попов, Ю.В. Рогов, Г.Э. Саруханян, В.В. Верещака

Приведены результаты численного исследования влияния энергетического разброса электронного пучка на распределение поглощённой дозы при двустороннем облучении. Показано изменение значения поглощённой дозы в критической точке в зависимости от ширины спектра электронного пучка. Установлена зависимость коэффициента неоднородности поглощённой дозы от энергетического разброса электронного пучка.

ВПЛИВ ЕНЕРГЕТИЧНОГО РОЗКИДУ ЕЛЕКТРОННОГО ПУЧКА НА РОЗПОДІЛЕННЯ ПОГЛИНЕНОЇ ДОЗИ

В.Т. Лазурик, В.М. Лазурик, Г.Ф. Попов, Ю.В. Рогов, Г.Е. Саруханян, В.В. Верещака

Наведено результати чисельного дослідження впливу енергетичного розкиду електронного пучка на розподіл поглиненої дози при двосторонньому опроміненні. Показано зміну значення поглиненої дози в критичній точці в залежності від ширини спектра електронного пучка. Встановлено залежність коефіцієнта неоднорідності поглиненої дози від енергетичного розкиду електронного пучка.